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JAN 80 D A HALL, R E TOWNSEND, J KNIPPA
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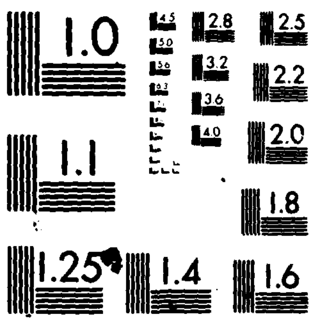

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THE IMPACT OF REMOTE FLY-AWAY SUBMERSIBLE OPERATIONS ON PERSONNEL ENDURANCE CAPABILITIES

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ABSTRACT

To obtain information on stress, fatigue, and work-rest cycles of submersible operators and system support personnel (SSP) members during an actual submarine rescue fly-away mission, 17 fly-away team members were monitored during the conduct of a 10-day simulated open-sea submarine rescue using the Deep Submergence Rescue Vehicle (DSRV), AVALON. Operators and crew members lived aboard the mother submarine which carried the DSRV from port to the site of the downed submarine and return. Demographic information, psychological measures, and environmental data were obtained during baseline, transit-out, in-port, and dive periods. The overall results supported previous findings[3], suggesting that a DSRV mission of the present duration and difficulty can be accomplished without exceeding the capabilities of the crew and support personnel. The trend of the changes, does, however, suggest that missions of longer duration may require scheduling of regular sleep periods for personnel to maintain performance.

INTRODUCTION

As deep submergence vehicles (DSVs) develop greater depth capabilities and are given longer duration missions, the physiological and psychological well-being of the operators and system support personnel (SSP) becomes of increasing importance in insuring successful completion of the mission. Establishment of baseline data on stress and fatigue in submersible operators and SSP is important in determining the safety of present operations and the reserve capability available in the event of unanticipated demands on performance.

During open sea diving operations, significant increases in sleep loss, fatigue, and mood disturbance among both divers and support personnel have been documented.[7,11] While operations involving deep submersibles differ in many respects from saturation diving situations, a number of the fundamental causes of psychological and physiological stress, and disruption of normal sleep-waking rhythms are still present, and may be potentiated by the greater duration and repetitive nature of submersible operations. Additionally, as extended fly-away capabilities for DSVs are developed the chances increase for added stressors such as significant time zone changes and coordinating efforts with foreign naval personnel and equipment.

There is presently little data available on the work, sleep disruption, and psychological and physiological stresses placed on submersible operators and SSP.[2] Data from an earlier DSRV fly-away showed no significant performance decrement over the short period of the simulated rescue.[3] However, results suggested that sleep-wake cycle disruptions occurred that would have produced performance impairment had the evolution been extended for a longer period of time. Data from a number of other situations have also clearly demonstrated that disruptions in sleep-wake cycles impair the accuracy and efficiency with which a variety of mental and physical tasks can be performed.[1]

One such DSV is the Deep Submergence Rescue Vehicle (DSRV) (Fig. 1), whose primary mission is to provide a quick reaction capability to rescue personnel from a disabled submarine. The U. S. Navy Deep Submergence Rescue System includes two DSRVs, a Submarine Rescue Unit (in San Diego, California), two ASR-21 class Submarine Rescue Ships, and a number of specifically configured mother submarines.

Briefly, the Rescue System functions as follows: upon receipt of deployment orders, the DSRV is transported from the homeport to the designated support ship, either directly by land on its Land Transport Vehicle or via C-5 or C-141 military aircraft. Upon arrival at the designated port nearest the location of the distressed submarine, the DSRV and its support equipment are loaded aboard a mother submarine, ASR, or ship of opportunity. Upon reaching the rescue site aboard the support ship, the DSRV is launched, piloted to the distressed submarine, and mated to the escape hatch, in as many round trips as necessary to remove all survivors and deliver them to the support ship. When operating with the ASR, personnel exit takes place with the DSRV hoisted aboard. With a mother submarine, the rescuees and the crew transfer into the forward room through the escape hatch in a submerged mating similar to the rescue mating.

The DSRV can carry up to 24 rescuees at one time. Thus, the rescue of the entire crew of a large nuclear submarine could require as many as seven or more trips. Each round trip would require several hours plus an hour or more turnaround time at the support ship for battery charging, life support replenishment, and reballasting. Additionally, the DSRV can mate with most modern submarines. The British, in fact, have modified a number of their

submarines to insure rescue mating compatability and to provide mother submarine capability. Other interested navies have also received the exact requirements for compatible mating surfaces which permit rescue matings at angles of up to 45°.

The purpose of the present study was to obtain information on stress, fatigue, and work-rest cycles of both submersible operators and system support crew members during an actual fly-away mission to a foreign nation, and to examine the reliability of previous findings. It was expected that the results would suggest possible areas of weakness or limitations which might affect the endurance capability of rescue operations.

METHODS

The submersible operators and support crew of the DSRV-2 AVALON were studied before and during a 10-day fly-away operation to Scotland, U.K., the purpose of which was to demonstrate the DSRV rescue capability and compatibility with British submarines. The evolution consisted of 3-day baseline, 2-day transit-out, 2-day in-port and 6-day dive data collection periods. Attempts were made to collect data consistently around the noon hour (local time) ± 1 hour, though operational demands required some delays of up to 9 hours.

Demographic Information.

At the beginning of the data collection period each participant was asked to complete a brief questionnaire designed to provide background information on age, education, and experience in submersibles and diving. Included were questions dealing with crew position, number of previous dives, submersible accidents, and diving or submersible-related medical problems.

Psychological Measures.

NHRC Sleep Log: The NHRC Sleep Log was a daily record of subjective evaluation of sleep. Included are self-ratings of difficulty falling asleep, time taken to fall asleep, number of awakenings, need for additional sleep, degree of restedness following sleep, number of hours of work in the previous 24 hours, and the clock time of sleeping and waking during the previous 24 hours. The Sleep Log was based on a similar instrument developed by Hartman and Cantrell[5] and used in previous diving studies,[10] as well as DSV studies.[3,4]

Stanford Sleepiness Scale (SSS): The SSS is a 7-statement self-rating scale to describe alertness and ability to function, ranging from alert, wide awake, to unable to remain awake.[6]

Profile of Mood States (POMS): The POMS is a 65-item, 5-point adjective rating scale which provides information on the mood or affective states of Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigor-Activity, Fatigue-Inertia, and Confusion-Bewilderment.[8] Subjects were requested to respond to POMS items according to how they felt at the time the form was filled out.

Environmental Data: The internal environment of the submersible was monitored by existing sensors. These data included PO_2, PCO_2, temperature, and humidity.

RESULTS

Demographic Information.

Table I shows the demographic data and indicates little intracrew variability except

in the area of the number of previous submersible dives logged by crew members. There were no significant medical problems or histories of experience with submersible accidents.

Psychological Measures.

Sleep Log: Table II shows the means and standard deviations for the Sleep Log variables affected by the different phases of the operation. The major changes in sleep occurred during the transit-out phase, with fragmentation of the sleep-wake cycle, reduced sleep time, decreased feelings of restedness, increased time needed to fall asleep, and decreased sleep time.

Stanford Sleepiness Scale (SSS): Significant changes in the SSS indicated decreased feelings of restedness which were relatively stable throughout the remainder of the mission. The trend of changes was consistent with the sleep loss indicated on the Sleep Log.

Profile of Mood States (POMS): Results of the analysis of the POMS data are shown in Table III as the means and standard deviations for each mood variable for each phase of data collection. Using the conservative Geisser-Greenhouse test, analysis of variance indicated significant changes in Vigor and Fatigue across operational phases. A X^2_x ANOVA by ranks,[12] which does not depend on assumptions of normality or homogeneity of variance, supported these findings. Feelings of Vigor were least during the in-port work phase while, as expected, Fatigue was greatest. In general, transit-out and in-port were the most disruptive of the four phases.

Environmental Data: Fluctuations in the environmental conditions (PO_2, PCO_2, temperature and humidity) were considered to be within normal limits and would not be expected to influence the physiological or psychological functioning of the crew.

DISCUSSION

The overall results of the present study were in the expected directions and confirmed the moderately disruptive effects on sleep and mood of short duration DSRV missions. Similar to a previous study,[3] the transit-out phase was shown to be the most disruptive in terms of sleep variables. Workloads, involving transit of the DSRV and predive preparations, increased moderately while the total sleep time and duration were decreased by over 50%. These resulted in decreased feelings of restedness and increased needs for sleep.

The decline in total sleep duration to 3 to 4 hours per 24 hour period was actually less than that found to be the minimum sleep duration necessary to sustain performance in situations where sleep duration was gradually and carefully reduced.[9] This abrupt decrease in total sleep time as well as the shorter sleep episode duration, both of which continued for the remainder of the mission, would be expected to result in increasing fatigue and corresponding impairment of performance had the mission been more demanding or the transit-out phase substantially extended. Furthermore, as the primary emphasis of the evolution was on demonstrating material capability of the British and U.S. systems, time pressure and rapidity of response were somewhat minimized; thus engendering less stress and sleep deprivation than would occur in a real emergency.

The results of the Profile of Mood States were consistent with the pattern of sleep disruption and work-hours per day. During the in-port phase, DSRV off-loading, transfer, and mother submarine set-up operations demanded long and continuous hours of work. The weather was cold, with considerable wind and occasional snow flurries, while some individuals were only marginally equipped with cold weather clothing. The resulting increased

fatigue and decreased vigor noted on the POMS undoubtedly was a significant contributing factor to the one traumatic injury (crush-laceration of the hand) which occurred during the mission. In addition, especially during this phase (in-port) subjects' reports of their moods (POMS) did not always coincide with the observed behavior patterns. On a few occasions subjects who were visibly stressed and fatigue resisted or refused to complete the POMS forms while later examination of the data showed no apparent indication of mood swings.

Points involving factors which were unique to this coordinated mission should also be noted. As is the British custom, alcoholic beverages were available on-board and most DSRV crew members indulged. Though this may have been a contributing factor in terms of mood, mood changes were very similar to those found in the previous study[3] involving only U. S. vessels where alcohol was not served aboard ship. Additionally, undersea visibility during operations was judged to be the worst possible and presented a rigorous test of capability. Yet, in spite of the mutual unfamiliarity with shipboard customs, equipment, and conditions, DSRV and British crew members appeared compatible with no discernible friction. Finally, there was no apparent evidence of performance impairment which would threaten the ability of the DSRV crew to successfully complete their rescue task.

Overall, these results support previous findings[3] that DSRV missions of the present duration and difficulty can be accomplished without exceeding crew or support personnel capabilities. However, the trends do suggest that longer or more demanding missions may require scheduling of regular sleep periods for personnel to maintain performance.

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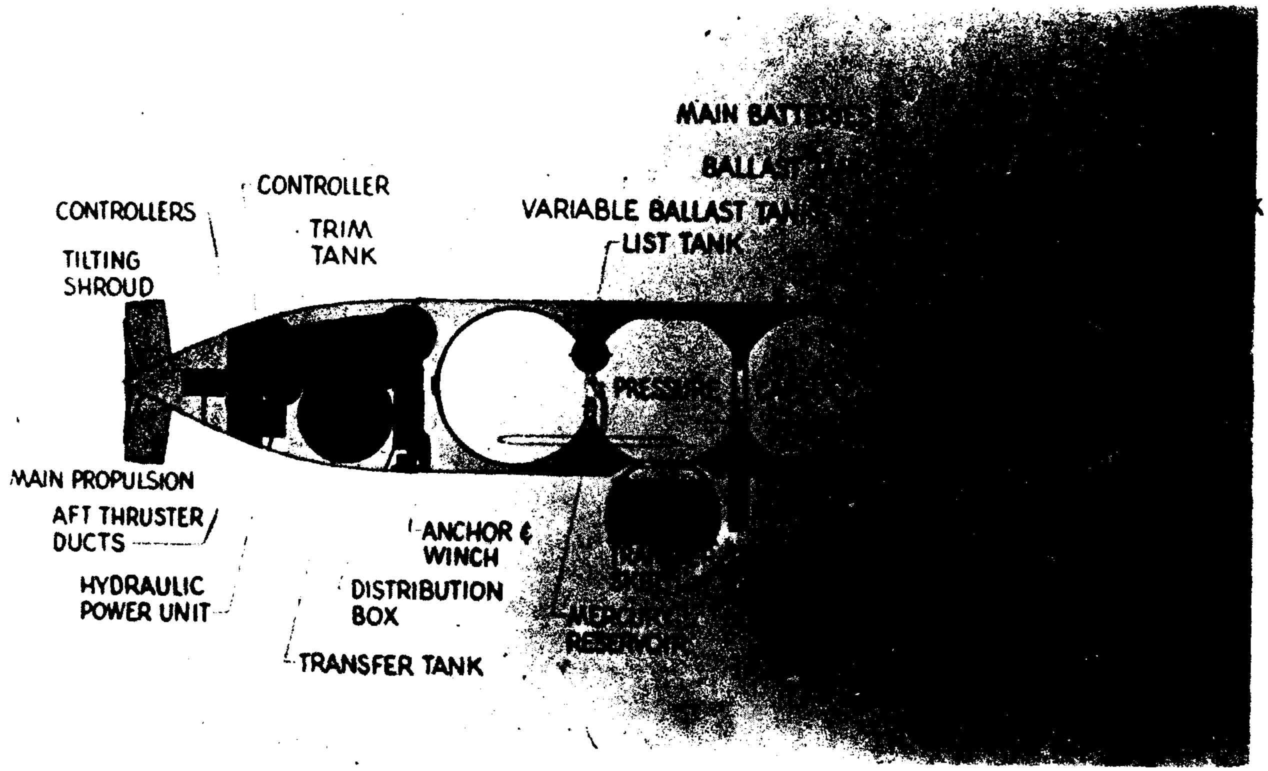

Fig. 1 Deep Submergence Rescue Vehicle Configuration

TABLE I
DEMOGRAPHIC DATA

Variable	Mean	S. D.
Age	28.8	5.5
Education	13.0	1.5 (none under 12)
Number of Previous Submersible Dives	35.6	42.7
Years in DSRV	1.3	1.3
Number of Dives in DSRV	30.1	37.2

TABLE II
SLEEP LOG

Variable	Baseline $\bar{X}$	Baseline S. D.	Transit Out $\bar{X}$	Transit Out S. D.	In Port $\bar{X}$	In Port S. D.	Dive $\bar{X}$	Dive S. D.	F	df 3/45 P =	†df 1/15 P =
Time to Fall Asleep	9.3	9.0	13.8	13.1	3.7	5.1	7.0	7.3	3.8	.017	ns
Need More Sleep	1.7	.4	1.1	.2	1.3	.4	1.4	.4	8.2	.000	< .05
How Well Rested	1.5	.5	2.6	.8	2.3	.8	2.0	.8	11.1	.000	< .005
No. Hrs/24	8.9	2.4	9.6	3.3	13.2	3.3	12.9	2.9	*9.1	.000	< .01
Total Sleep Duration	7.1	1.1	3.3	1.3	6.9	2.2	6.8	2.1	*19.8	.000	< .001
Sleep Episode Duration	6.5	1.7	3.0	1.8	5.0	2.3	4.6	1.4	*9.1	.000	< .01
SSS	1.6	.7	2.7	1.1	2.4	.9	2.4	1.1	5.6	.002	< .05

*This was a 40-hr period and analysis was done on prorated data.
†Geisser-Greenhouse Test

TABLE III
PROFILE OF MOOD STATES

	Baseline $\bar{X}$	Baseline S. D.	Transit-Out $\bar{X}$	Transit-Out S. D.	In Port $\bar{X}$	In Port S. D.	Dive $\bar{X}$	Dive S. D.	F	df 3/45 P =	†df 1/15 P =	X^2_r	df/3 P =
Depression	2.4	2.7	2.9	4.54	*3.0	3.5	Δ2.4	2.4	.24	ns	–	.9	–
Vigor	Δ22.7	5.0	18.5	6.8	*15.8	6.5	16.8	6.9	11.44	< .001	< .005	19.4	< .001
Fatigue	Δ4.2	4.5	6.6	4.2	*10.2	6.6	7.3	6.3	5.64	< .002	< .05	10.7	< .02
Anger	Δ3.6	3.7	4.2	6.0	5.3	7.9	*5.4	7.2	.64	ns	–	1.2	–
Tension	Δ4.9	3.1	*6.5	3.2	5.6	3.6	5.2	4.3	1.40	ns	–	7.2	–
Confusion	Δ3.2	2.6	3.6	2.0	*4.9	3.7	4.4	2.9	1.75	ns	–	2.7	–

Extreme Scores: * = negative mood indicator; Δ = positive mood indicator
†Geisser-Greenhouse Test

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(U) During open-sea submersible operations, particularly those involving quick reaction rescue missions, the physiological and psychological well-being of the operators and surface support personnel (SSP) becomes of increasing importance in insuring successful completion of the event. The purpose of this study was to obtain information on stress, fatigue, and work-rest cycles of both submersible operators and surface support crew members during an actual submarine rescue fly-away mission. Six operators and seven SSP were monitored

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during the conduct of a six day trial open-sea submarine rescue evolution using the Deep Submergence Rescue Vehicle (DSRV), Mystic. Operators and crew members lived aboard the mother submarine which carried the DSRV from port to the site of the downed submarine and return. Demographic information, psychological measures, performance measures and environmental data were obtained during pre-deployment, transit-out, at dive site, and transit-in periods. The overall results suggested that a DSRV mission of the present duration and difficulty can be accomplished without exceeding the capabilities of the crew and support personnel. The trend of the changes, do, however, suggest that missions of longer duration may require scheduling of regular sleep periods for personnel to maintain performance. Additionally, it is felt that monitoring and analysis of demographic, operational, and environmental data should aid in the ongoing assessment of the safety of current and future open-sea evolutions, thus providing guidance to operators in the event that deeper, more time-critical missions occur.